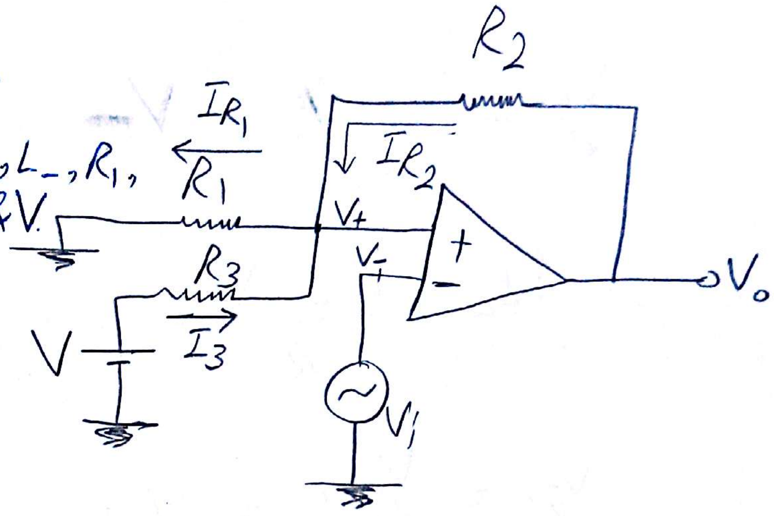
Multivibrators Sheet

(1) Bistable multivibrators:

a) Derive an expression for V_{TH} & V_{TL} in terms of L_+, L_-, R_1, R_2, R_3 & V.



b) Let $L_+ = -L_- = 13V$

$V = 15V$

$R_1 = 10k\Omega$

$V_{TL} = 4.9V$, $V_{TH} = 5.1V$

Find R_2 & R_3

Solution

a) Assume $V_o = L_+$

At $V_i = V_{TH}$

$\therefore V_- = V_+ = V_{TH}$

$\Rightarrow$ Applying KCL:

$$I_{R_1} = I_{R_2} + I_{R_3}$$

$$\therefore \frac{V_+ - 0}{R_1} = \frac{V_o - V_+}{R_2} + \frac{V - V_+}{R_3}$$

$$\therefore \frac{V_{TH}}{R_1} = \frac{L_+ - V_{TH}}{R_2} + \frac{V - V_{TH}}{R_3}$$

$$\therefore V_{TH}\left[\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right] = \frac{V}{R_3} + \frac{L_+}{R_2}$$

$$\therefore V_{TH} = \left(\frac{V}{R_3} + \frac{L_+}{R_2}\right)(R_1 // R_2 // R_3) \Leftarrow$$

$\Rightarrow$ To get V_{TL}: Assume $V_o = L_-$

$$V_+ = V_- = V_{TL}$$

$$\frac{V_+}{R_1} = \frac{V_o - V_+}{R_2} + \frac{V - V_+}{R_3}$$

$$\therefore \frac{V_{TL}}{R_1} = \frac{L_- - V_{TL}}{R_2} + \frac{V - V_{TL}}{R_3}$$

$$\therefore V_{TL} = \left(\frac{V}{R_3} + \frac{L_-}{R_2}\right)(R_1 // R_2 // R_3) \Leftarrow$$

b) $\Rightarrow V_{TH} = \left(\frac{V}{R_3} + \frac{L_+}{R_2}\right)(R_1 // R_2 // R_3)$

$$\therefore 5.1 = \frac{15}{R_3} + \frac{13}{R_2} \cdot \frac{1}{\frac{1}{10k} + \frac{1}{R_2} + \frac{1}{R_3}}$$

$$\therefore \frac{5.1}{10k} + \frac{5.1}{R_2} + \frac{5.1}{R_3} = \frac{15}{R_3} + \frac{13}{R_2}$$

$$\therefore 0.51 = \frac{7.9}{R_2} + \frac{9.9}{R_3} \longrightarrow (1)$$

$$\Rightarrow V_{TL} = \left(\frac{V}{R_3} + \frac{L_-}{R_2}\right)(R_1 // R_2 // R_3)$$

$$\therefore 4.9 = \left(\frac{15}{R_3} - \frac{13}{R_2}\right) \cdot \frac{1}{\frac{1}{10k} + \frac{1}{R_2} + \frac{1}{R_3}}$$

$$\therefore 0.49 = \frac{-17.9}{R_2} + \frac{10.1}{R_3} \longrightarrow (2)$$

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Multiplying ① by $\frac{10.1}{9.9}$:

$\therefore 0.52 = \frac{8.06}{R_2} + \frac{10.1}{R_3} \rightarrow$ ③

Solving ② & ③ together:

$\therefore R_2 = 856.8k\Omega$

$R_3 = 19.8k\Omega$

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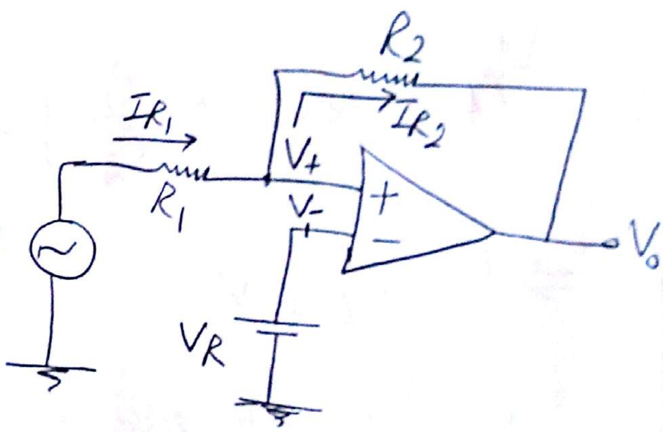
(2) a) Derive an expression for V_{TL} & V_{TH}.



b) $L_+ = -L_- = V$

$R_1 = 10k\Omega$

$V_{TL} = 0V$, $V_{TH} = \frac{V}{10}$

Find R_2 and V_R

Solution

a) For V_{TH}: Assume $V_o = L_-$

$I_{R_1} = I_{R_2}$

$$\frac{V_i - V_+}{R_1} = \frac{V_+ - V_o}{R_2}$$

$$\therefore \frac{V_{TH} - V_R}{R_1} = \frac{V_R - L_-}{R_2}$$

$$\therefore V_{TH} = V_R\left[1 + \frac{R_1}{R_2}\right] - \frac{R_1}{R_2}L_-$$

$\Rightarrow$ For V_{TL} : Assume $V_o = L_+$

$I_{R_1} = I_{R_2}$

$\therefore \dfrac{V_i - V_R}{R_1} = \dfrac{V_R - V_o}{R_2}$

$\therefore \dfrac{V_{TL} - V_R}{R_1} = \dfrac{V_R - L_+}{R_2}$

$\therefore V_{TL} = V_R \left[1 + \dfrac{R_1}{R_2}\right] - L_+ \dfrac{R_1}{R_2}$ $\Leftarrow$

b) $\Rightarrow$ For $V_{TL} = 0V$

$\therefore 0 = V_R \left[1 + \dfrac{10k}{R_2}\right] - \dfrac{10}{R_2} V \rightarrow (1)$

$\Rightarrow$ For $V_{TH} = \dfrac{V}{10}$

$\therefore \dfrac{V}{10} = V_R \left[1 + \dfrac{10k}{R_2}\right] + \dfrac{10}{R_2} V \rightarrow (2)$

Solving (1) & (2):

$\therefore R_2 = 200k\,\Omega$

$\therefore V_R = 47.62 * 10^{-3} V$

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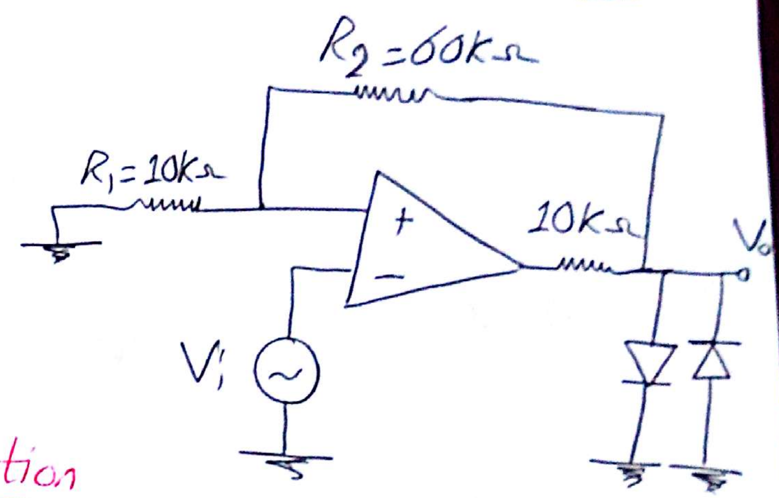
3) Sketch the transfer Characteristics ($V_o - V_i$)

$V_D = 0.7V$

Op-Amp Sat. Level $= \pm 12V$



$L_+ = 0.7V$

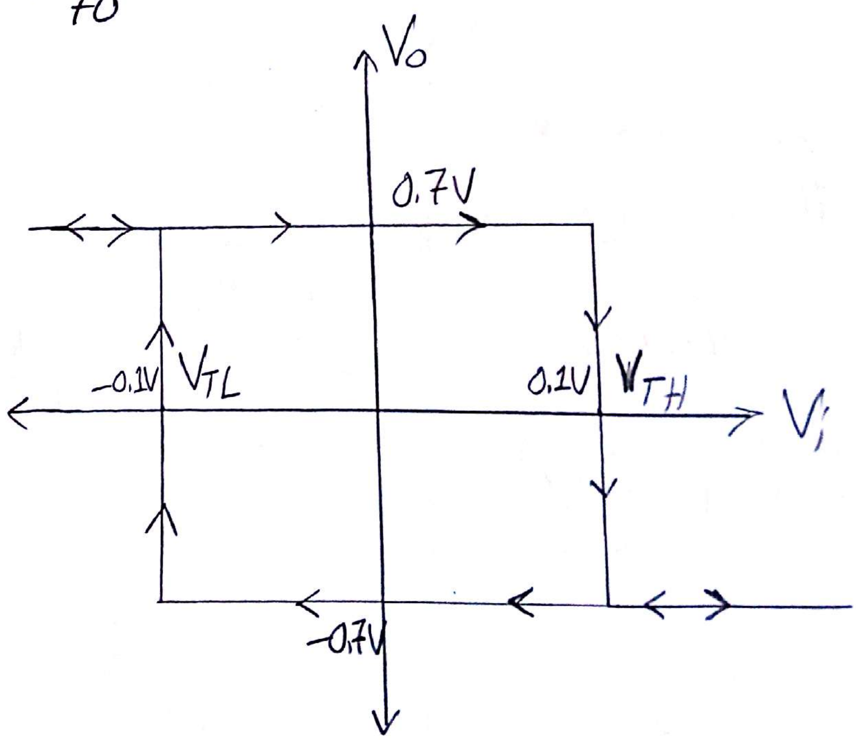
$L_- = -0.7V$

Solution

$\Rightarrow$ Inverting Bistable

$$V_{TH} = \beta L_+ = \frac{10}{60+10} * 0.7 = 0.1V$$

$$V_{TL} = \beta L_- = \frac{10}{70} * -0.7 = -0.1V$$



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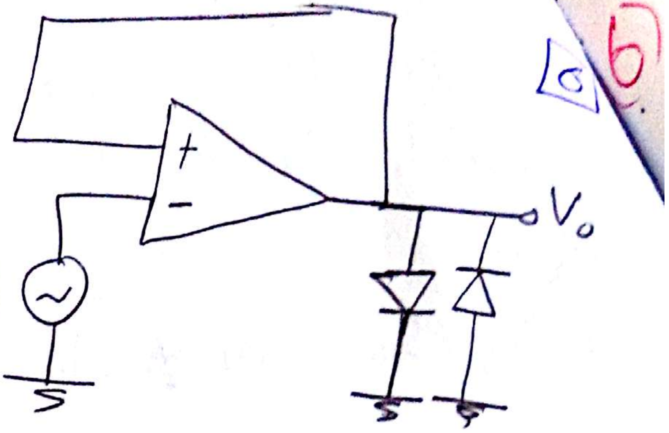
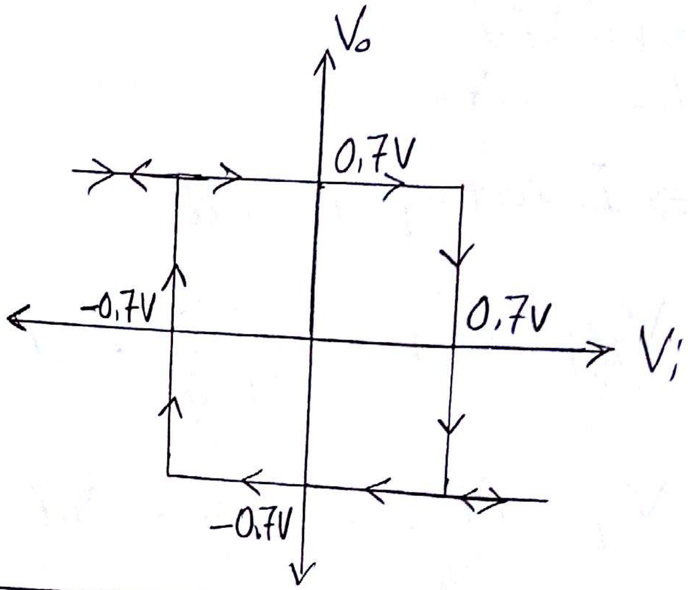
(4) Sketch (V_o-V_i) Ch/c.



Solution

$V_{TH} = 0.7V$, $V_{TL} = -0.7V$



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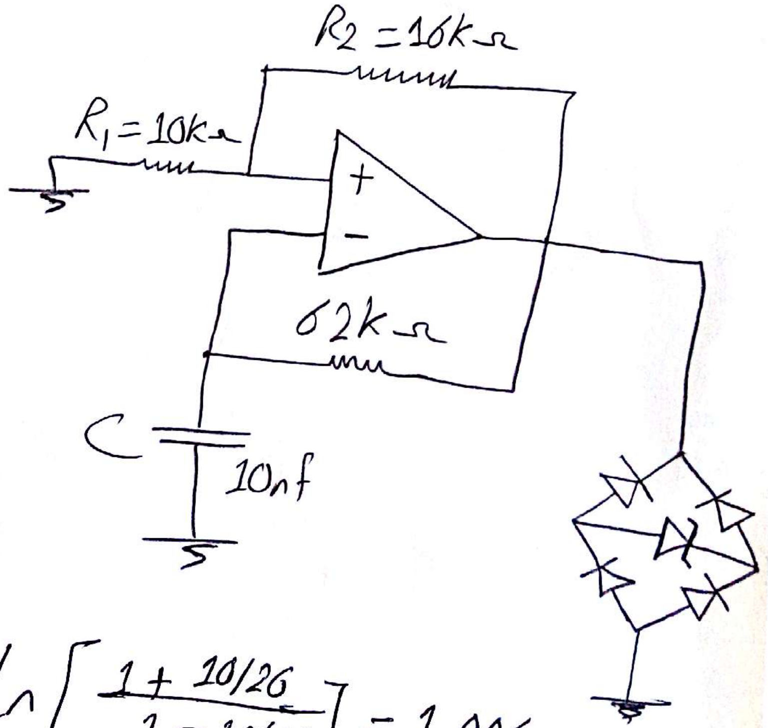
(5) Find the oscillation frequency.



Solution

$$T = 2\tau \ln\left(\frac{1+\beta}{1-\beta}\right)$$

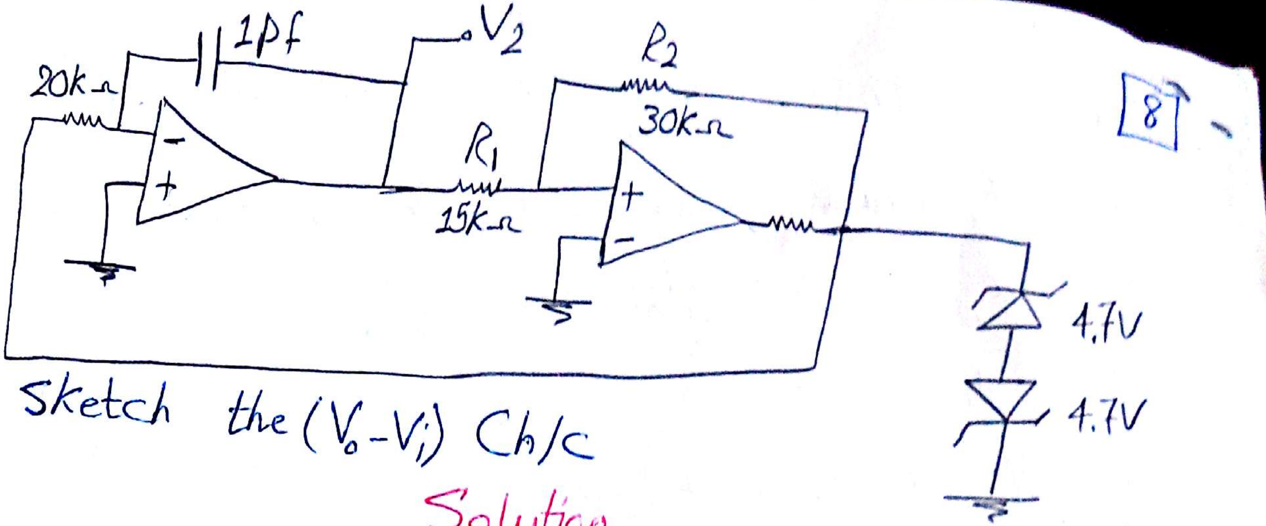
$$\tau = RC$$

$$\beta = \frac{R_1}{R_1+R_2} = \frac{10}{26}$$

$$\therefore T = (2 * 62*10^3 * 10*10^{-9}) \ln\left[\frac{1+10/26}{1-10/26}\right] = 1.006ms$$

$$\therefore f = \frac{1}{T} = 994.5Hz$$

(7).



Sketch the $(V_o - V_i)$ Ch/c

Solution

$$V_{TH} = -L_- \frac{R_1}{R_2} = -2.7V$$

$$V_{TL} = -L_+ \frac{R_1}{R_2} = 2.7V$$

$$L_+ = 4.7 + 0.7 = 5.4V$$

$$L_- = -(4.7 + 0.7) = -5.4V$$

$$T_1 = RC \, \frac{V_{TH} - V_{TL}}{L_+} = 20 * 10^3 * 10^{-12} * \frac{5.4}{5.4} = 20ns$$

$$T_2 = 20ns$$

$$\therefore T = 40ns$$